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**Cheng et al.**

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(54) **COMPOUND JK12A AND PREPARATION THEREOF**

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**C07D 475/04** (2006.01)

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CPC ..... **C07D 487/18** (2013.01); **C07D 475/04** (2013.01)

(58) **Field of Classification Search**  
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USPC ..... 544/251; 514/250  
See application file for complete search history.

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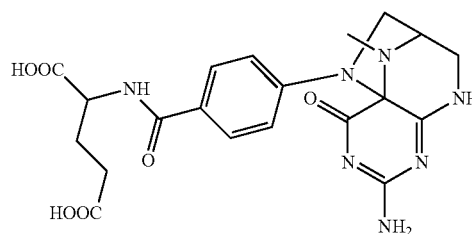
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(57) **ABSTRACT**

The present invention relates to a compound [4-(2-amino-10-methyl-4-oxo-6,7,8,9-tetrahydro-4a,7-cycloimino-pyrimido [4,5-b][1,4]diazepine-5(4H)-yl)benzoyl]-glutamate (JK12A for short) with the structure in Formula I. The present invention also relates to the crystal form and salt of the compound JK12A, and preparation method and applications thereof. The compound JK12A of the present invention can be used to prepare drugs as an active ingredient for medicament or food additives.



I

**26 Claims, 11 Drawing Sheets**

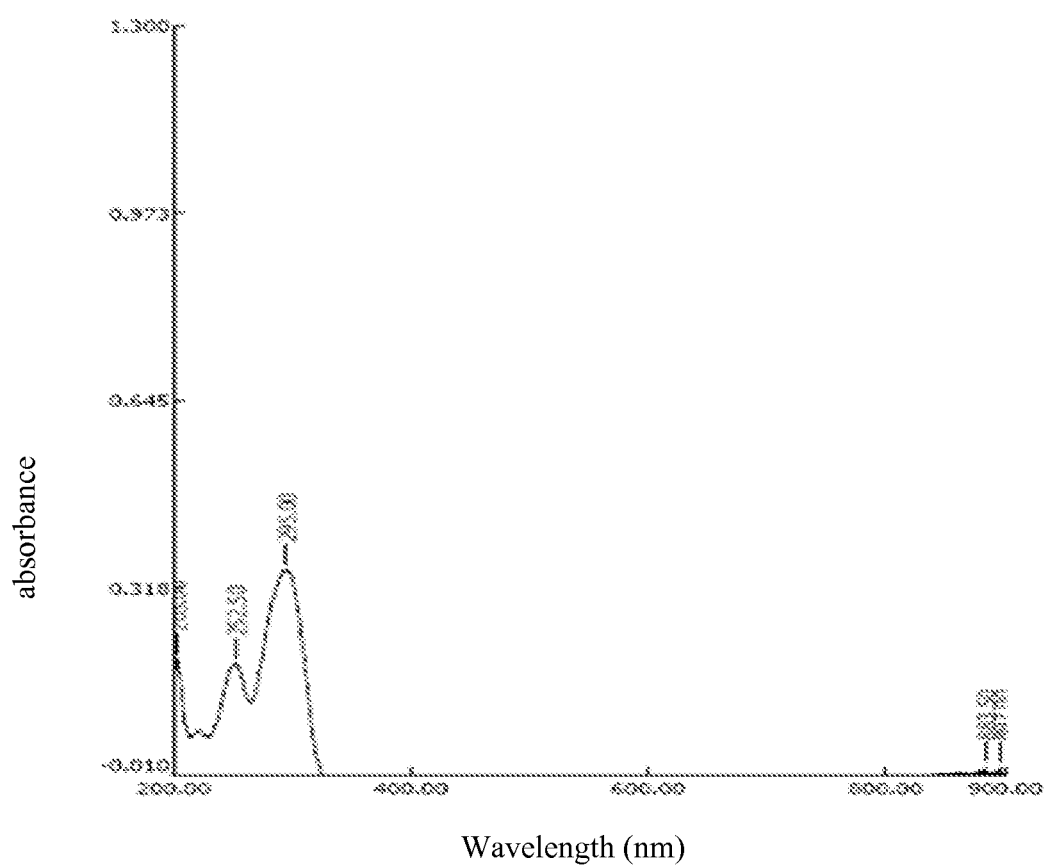
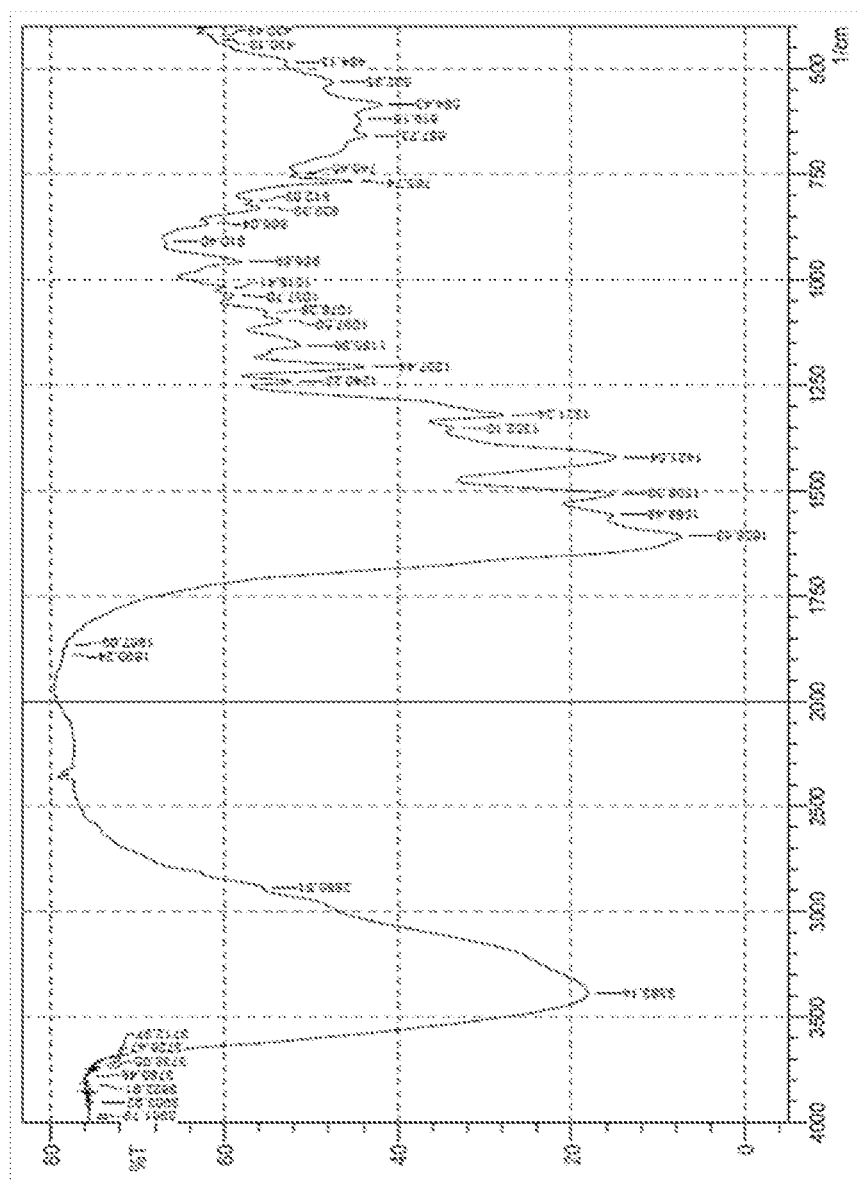


Figure 1



### Figure 2

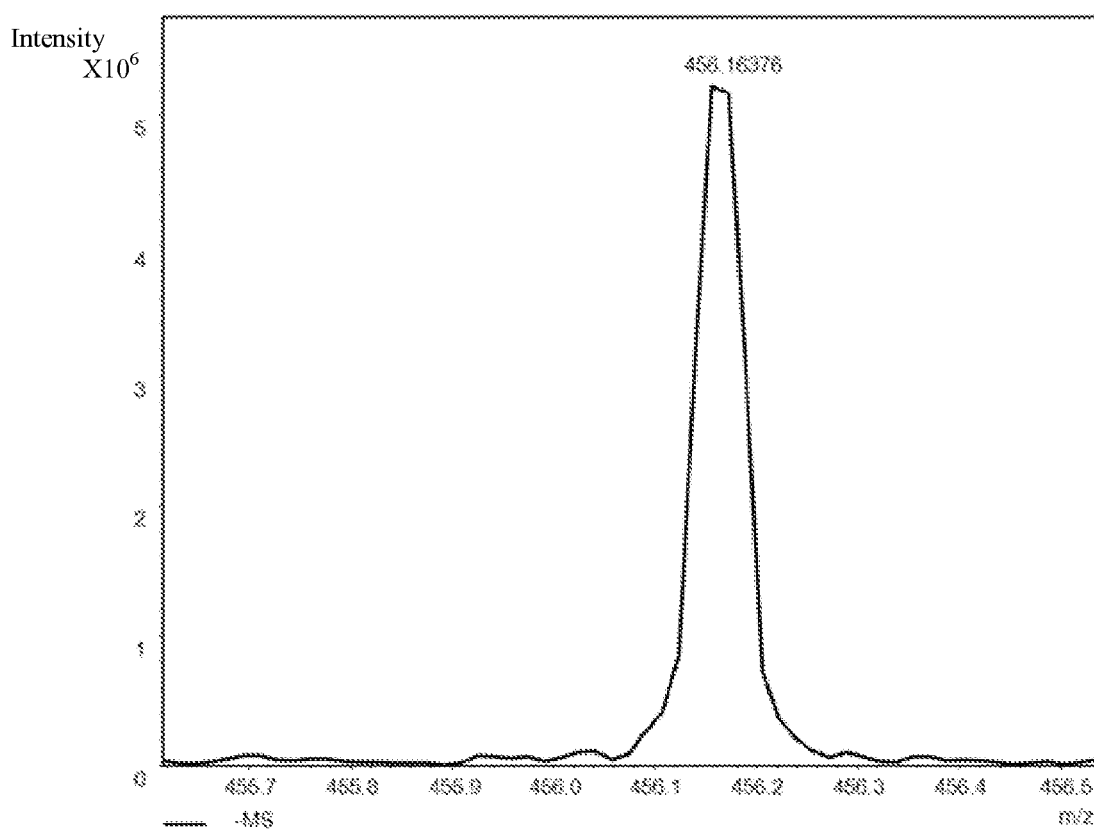


Figure 3

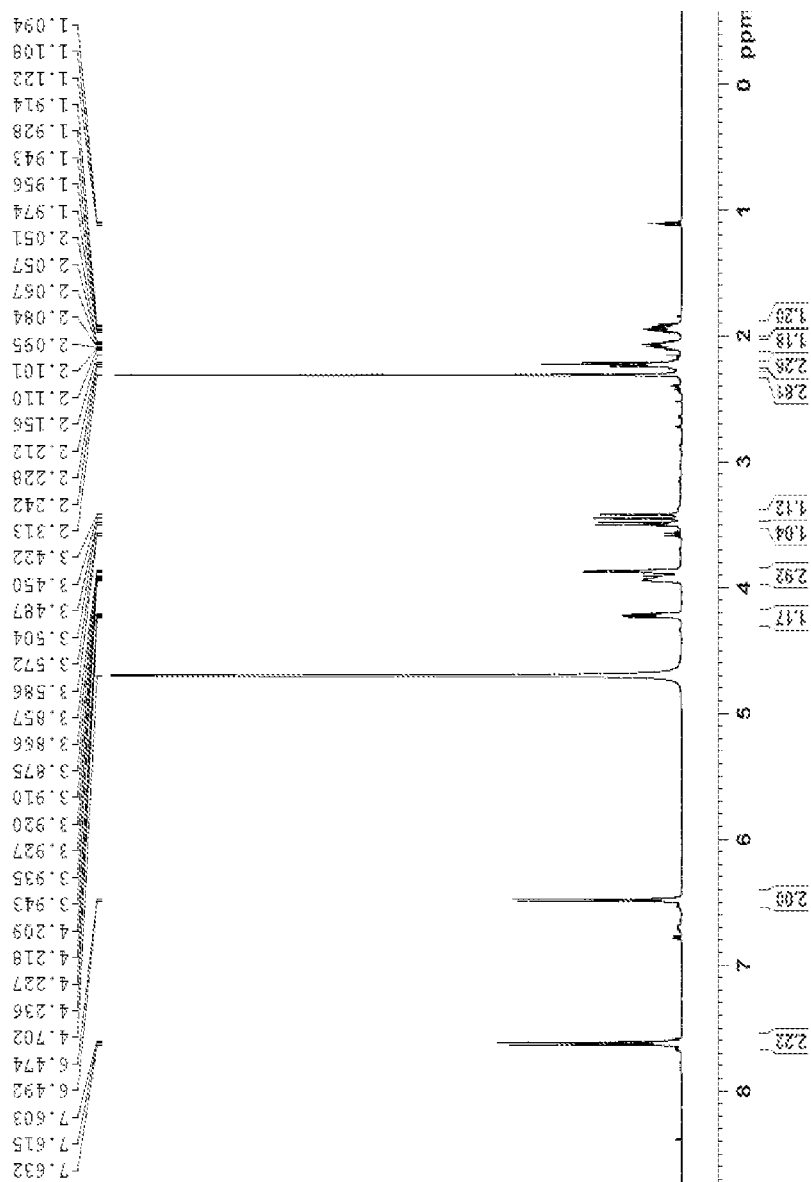


Figure 4

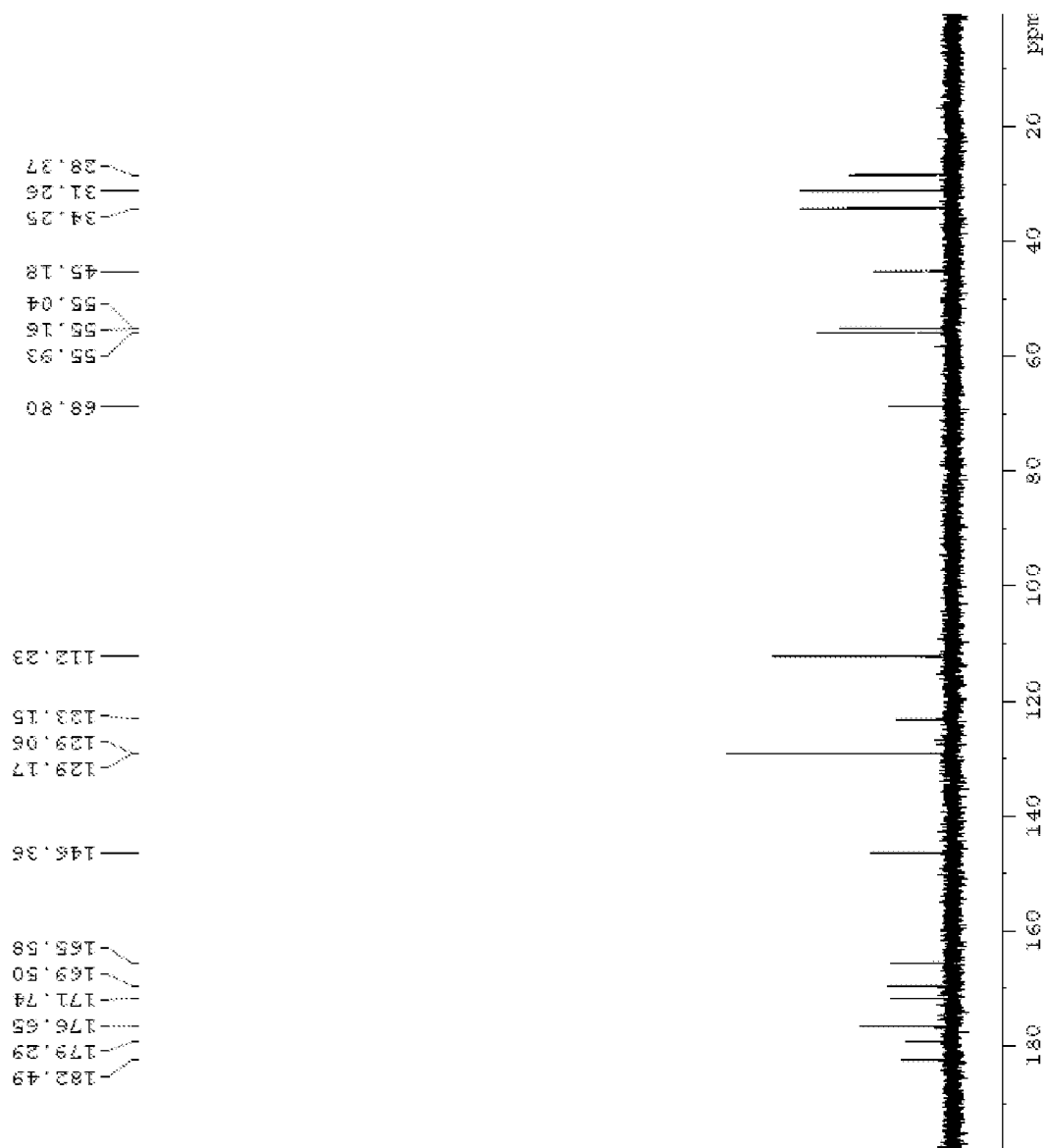


Figure 5

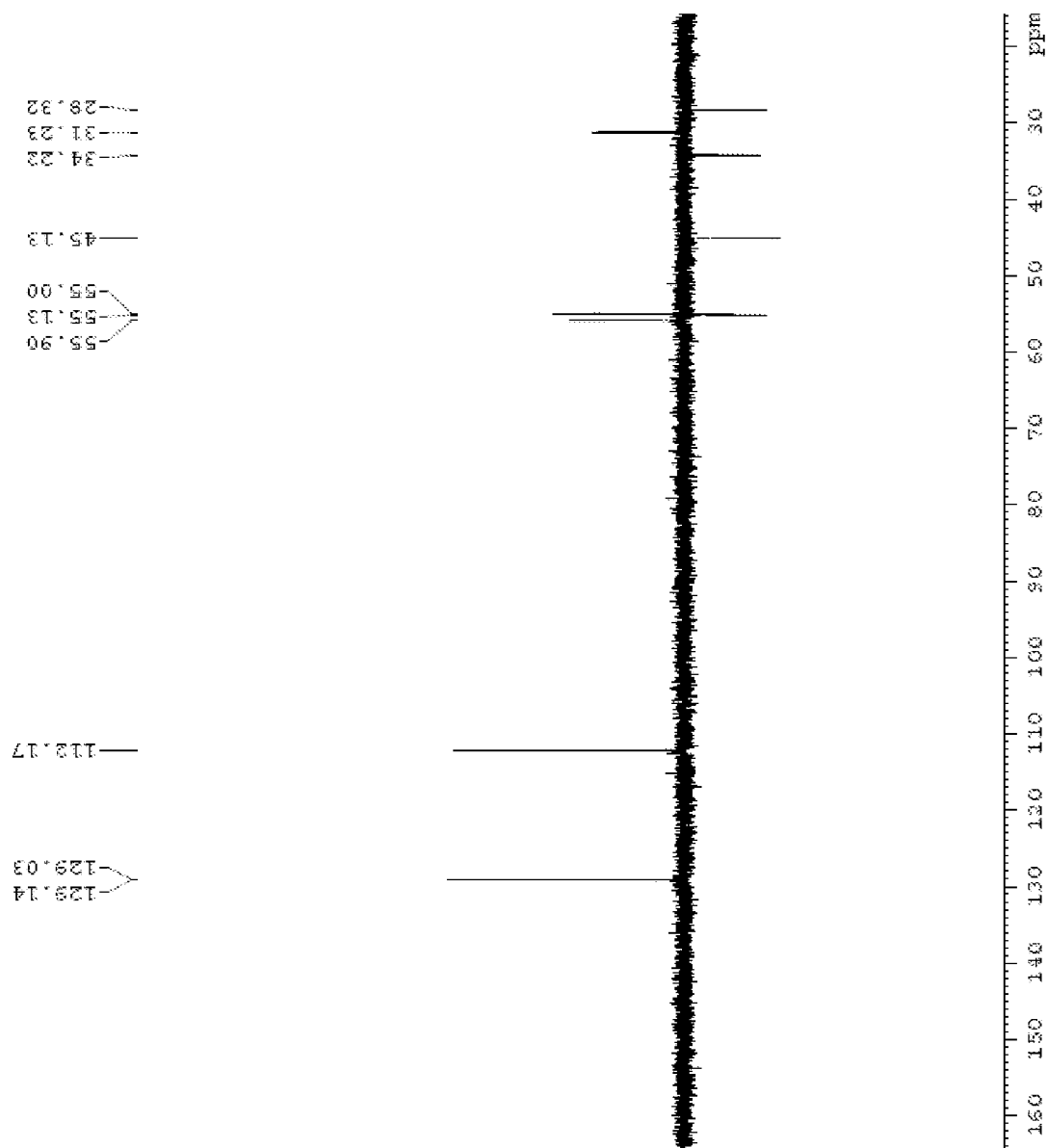
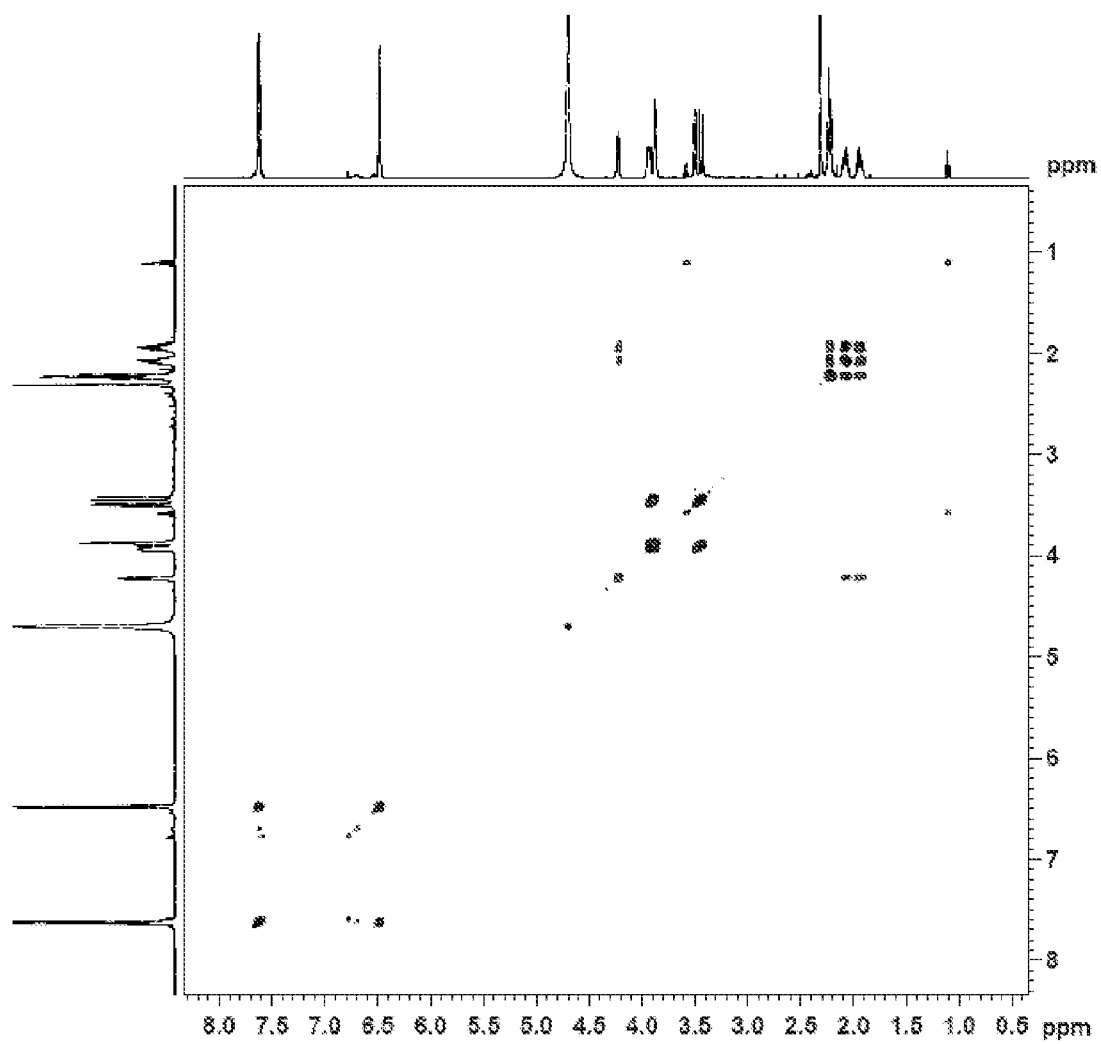
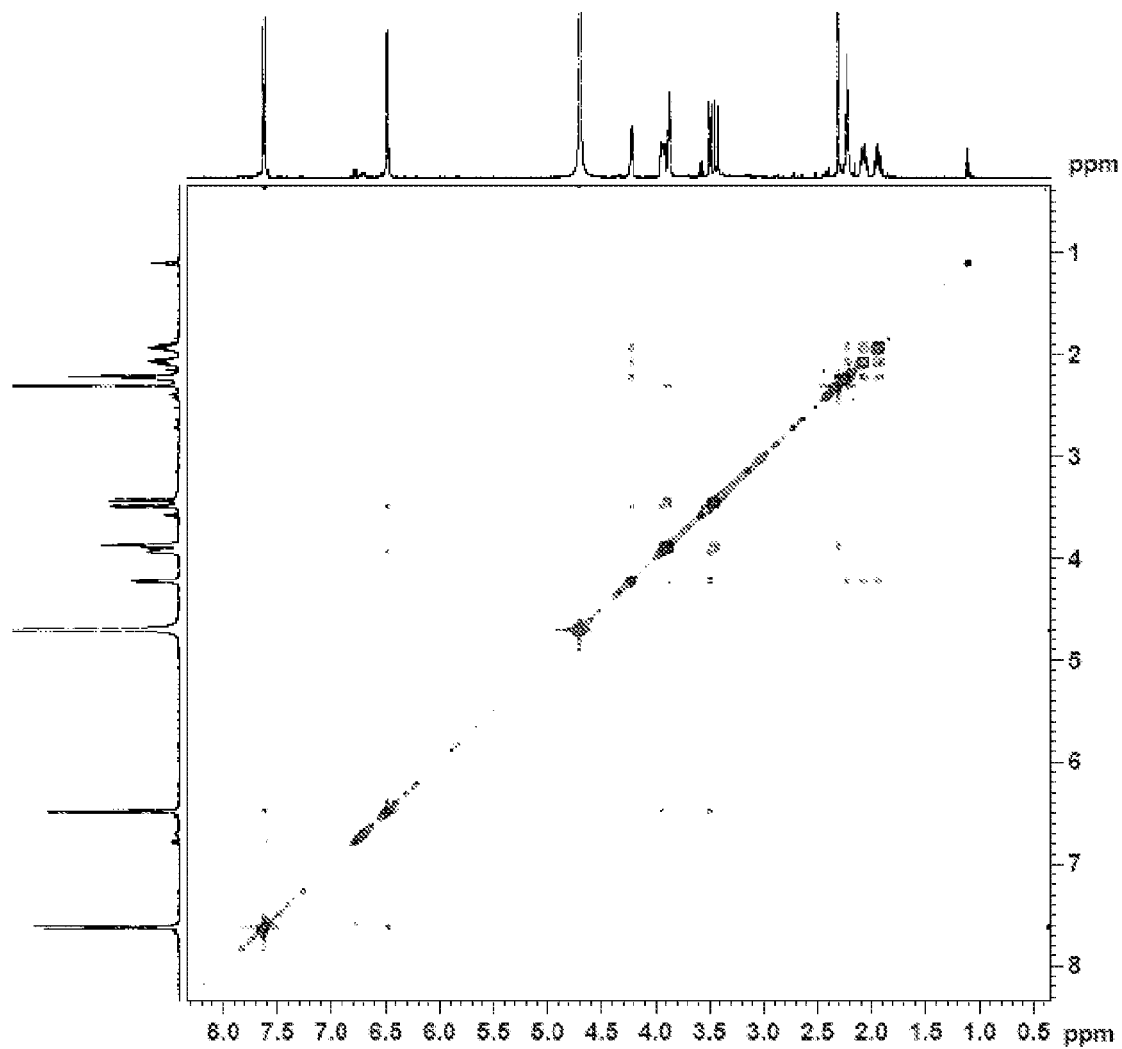
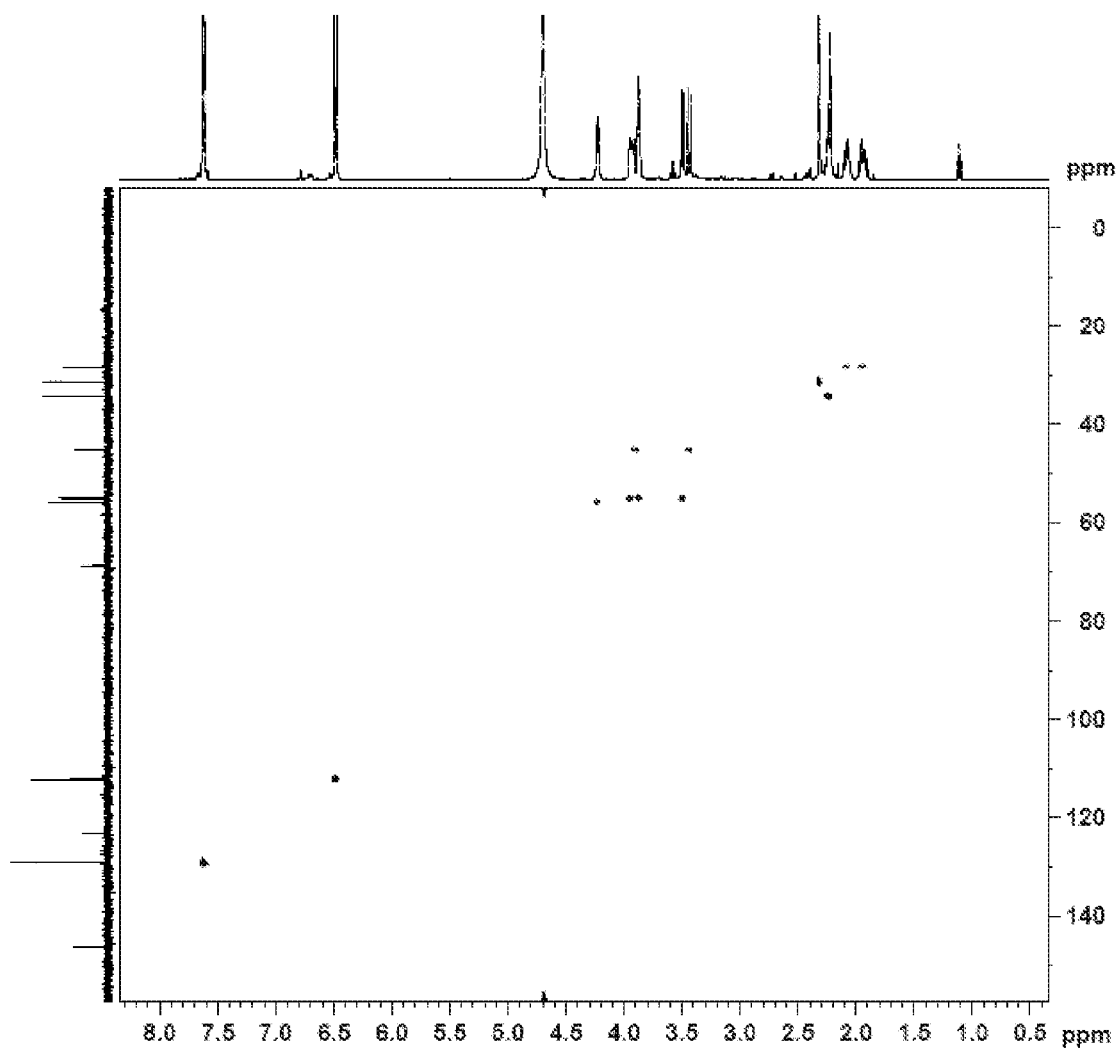
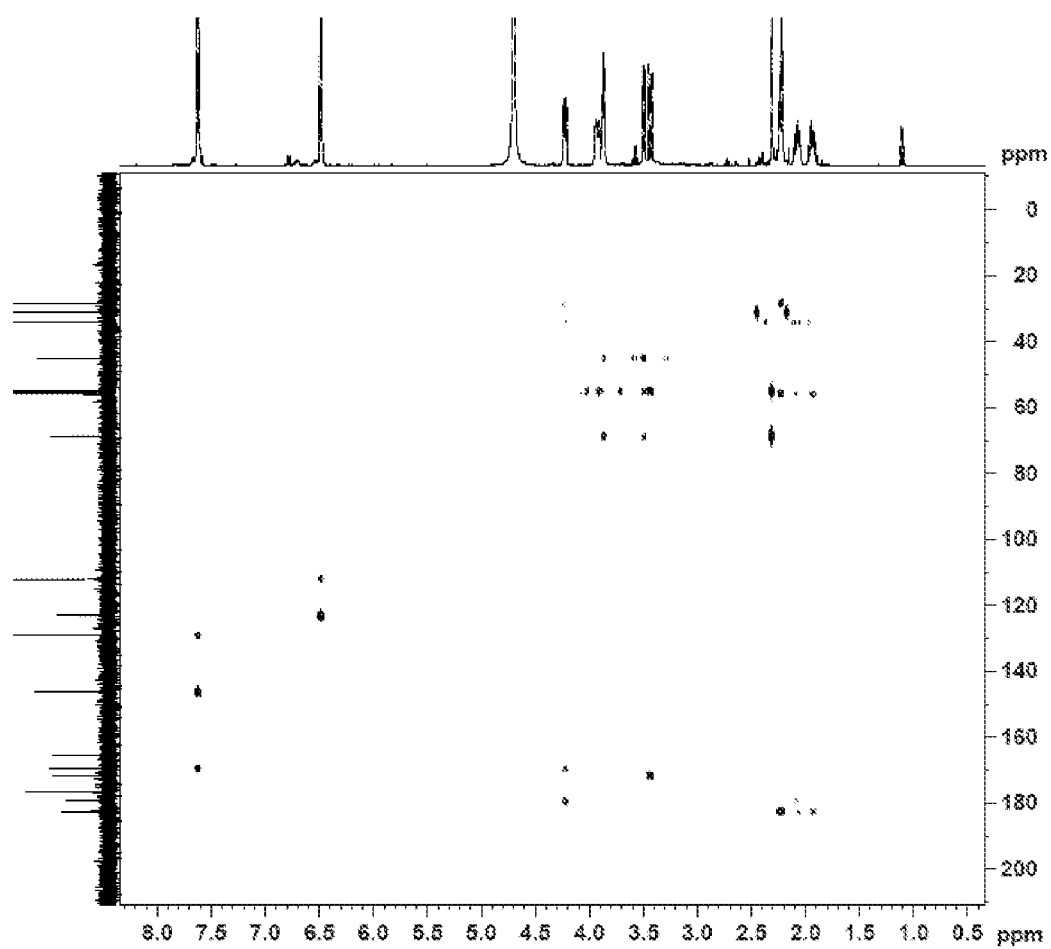


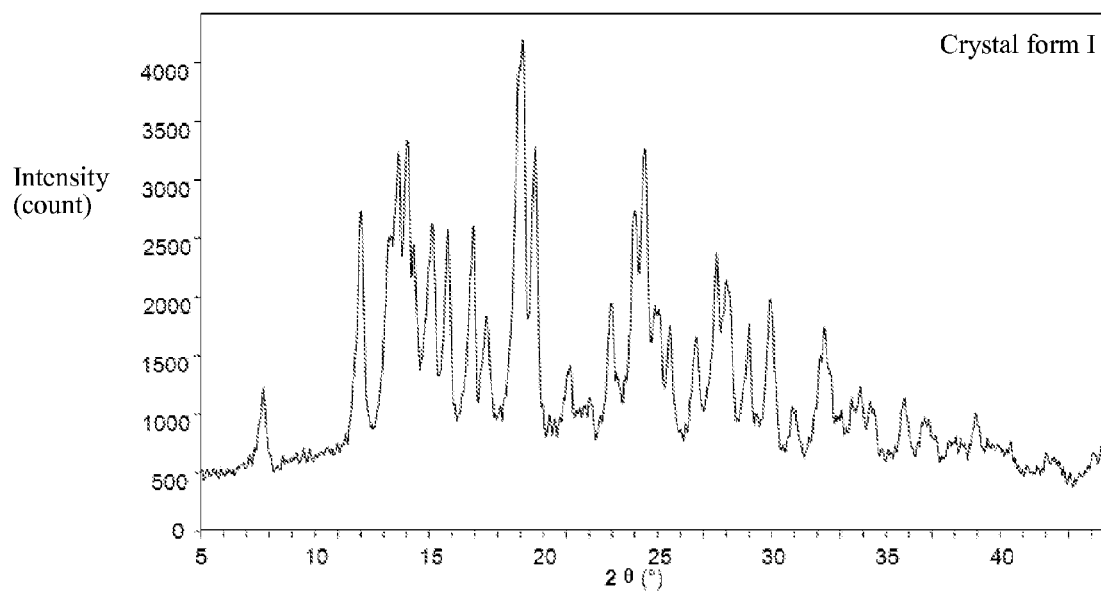
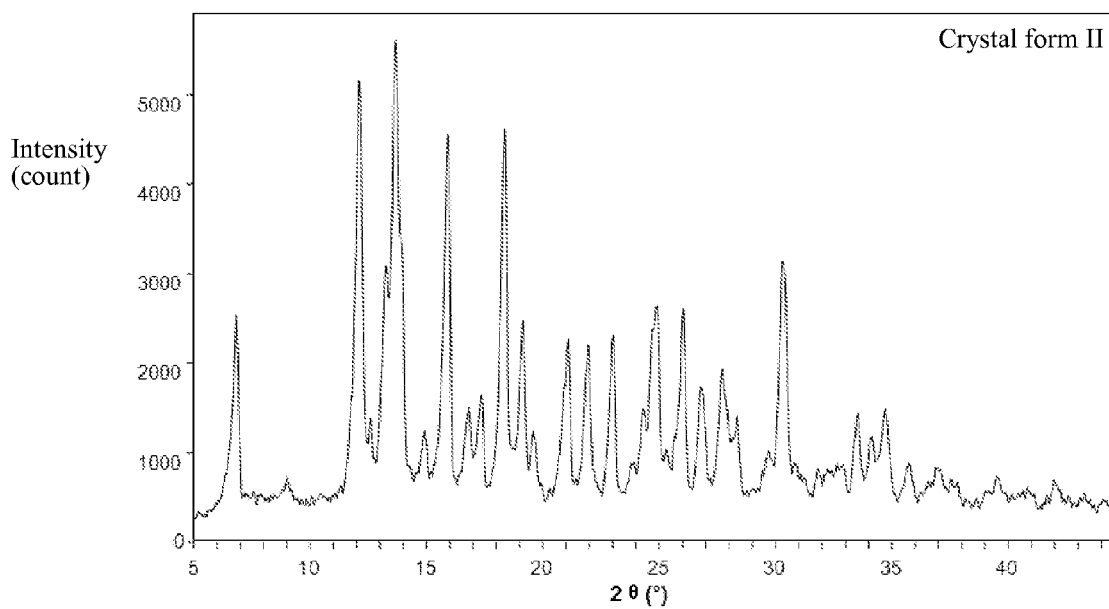
Figure 6

**Figure 7**

**Figure 8**

**Figure 9**

**Figure 10**

**Figure 11****Figure 12**

# 1

## COMPOUND JK12A AND PREPARATION THEREOF

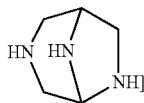
### TECHNICAL FIELD

The present invention relates to the field of heterocyclic compound (CO7D), wherein, the heterocyclic compound contains two or more heterocyclic rings, and nitrogen is the only heterocyclic atom of the identical cyclic system, including at least a hexatomic ring with at least one nitrogen atom (471/00). In particular, the present invention relates to a compound [4-(2-amino-10-methyl-4-oxo-6,7,8,9-tetrahydro-4a,7-imine-pyrimido[4,5-b][1,4]diazepine-5(4H)-yl)benzoyl]-glutamic acid, as well as its crystal form, a preparation method and applications.

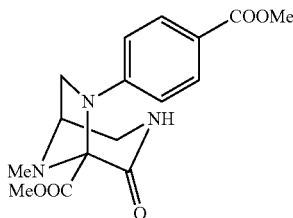
### BACKGROUND ART

The compound with triazabicyclo[3,2,1]octane structure has attracted great attention from chemists and medical experts because of its unique molecular structure.

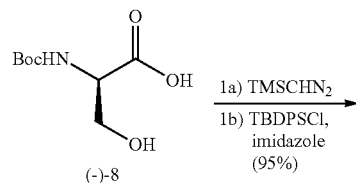
Aplaminal is the first compound that is found to have triazabicyclo[3,2,1]



octane structure, and was first separated by Takeshi Kuroda and Hideo Kigoshi et al. from *Aplysia (Varia) kurodai* in the year of 2008 (Org. Lett., Vol. 10, No. 3, p489-491, 2008). Its specific structure is as follows:

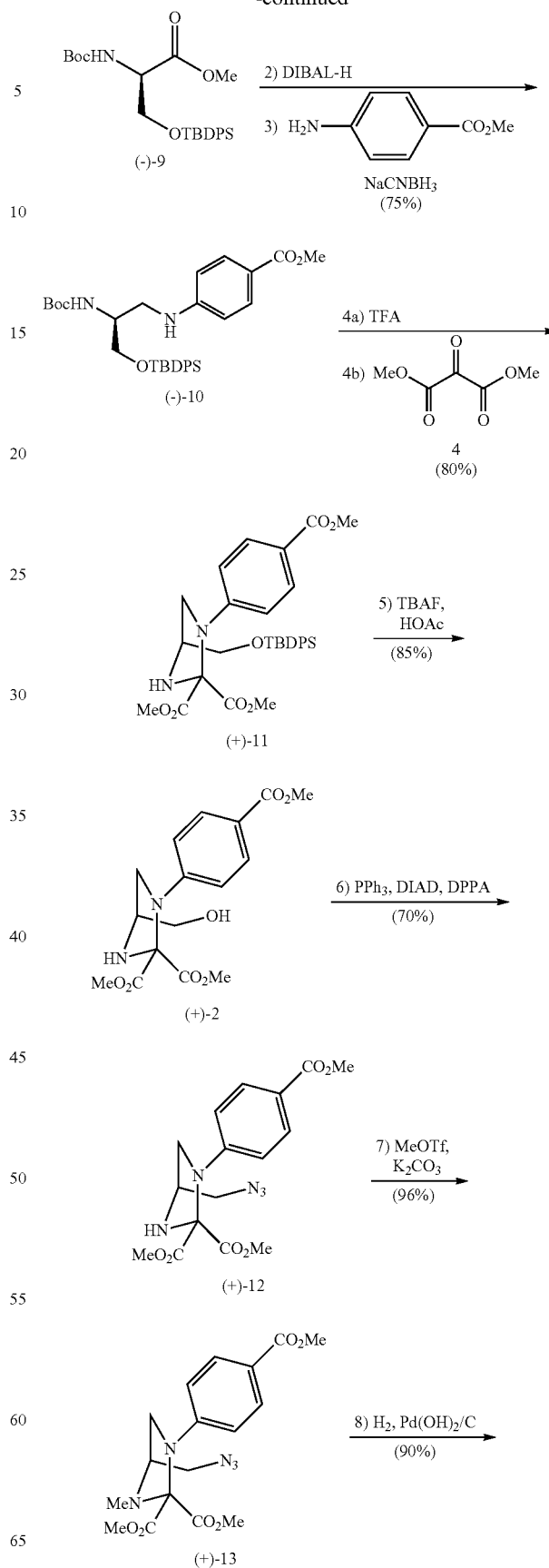


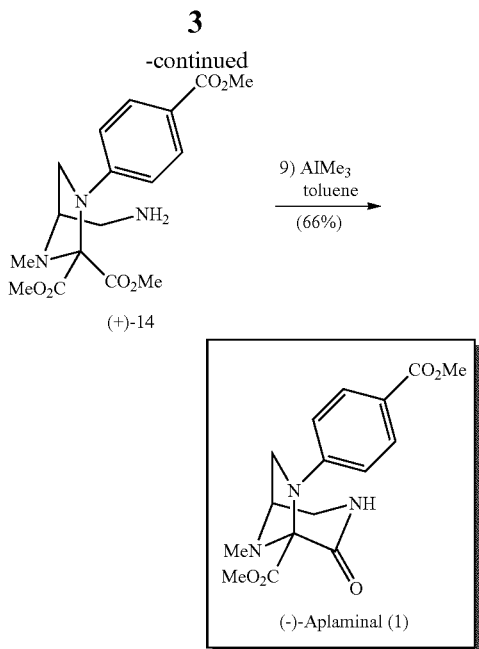
The literature characterizes the structure of Aplaminal through NMR and single crystal X-ray diffraction. It is reported that Aplaminal has the cytotoxicity against HeLa S3 cells ( $IC_{50}=0.51$  ug/mL). More clinical trials are still being researched. The preparation of Aplaminal through biological extraction involves extremely high cost and produces a very low yield. Generally, only 2 mg of Aplaminal can be extracted from 18 kg of *aplysia*. Therefore, Amos B. Smith III and Zhuqing Liu et al. (Org. Lett., Vol. 10, No. 19, p4363-4365, 2008) prepared Aplaminal through synthesis with N-Boc-(D)-serine as the raw material in 9 reaction processes, including hydroxyl protection, condensation, reduction, etc., obtaining a yield of 17%. The specific reaction process is as follows:



## 2

### -continued





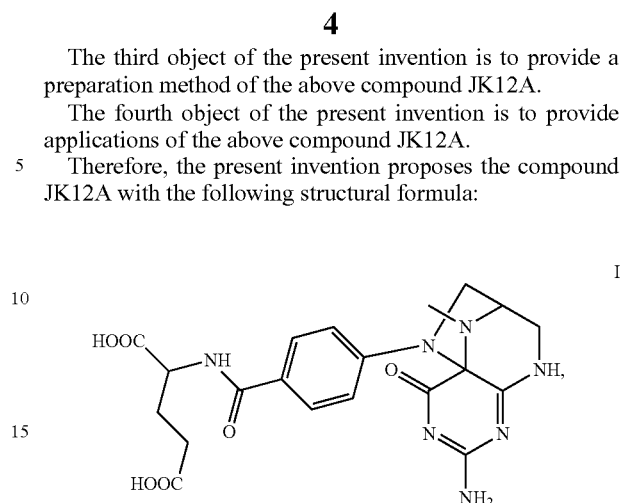
However, it is also very difficult to synthesize the compound with a triazabicyclo[3,2,1]octane structure. The above synthetic method of Aplaminal suffers from redundant reaction processes; expensive reagents such as diisobutylaluminum hydride (Dibal-H), Pd and Pt; difficult pilot process control; less safety and low yield; and is also not applicable for industrial production.

At present, there are many reports of other triazacyclo compounds. The patent document CN1864663 discloses the pharmaceutical compositions of 5,7,14-triazatetracyclo[10.3.1.0(2,11).0(4,9)]-hexadeca-2(11),3,5,7,9-pentaene. The patent document CN102282148A discloses 11-(2-pyrrolidin-1-yl-ethoxy)-14,19-dioxo-5,7,26-triazatetracyclo[19.3.1.1(2,6).1(8,12)]heptacos-1(25),2(26),3,5,8,10,12(27),16,21,23-decaene citrate salt. The patent document CN1509288 discloses the citrate salt of 5,8,14-triazatetracyclo[10.3.1.0(2,11).0(4,9)]-hexadeca-2(11),3,5,7,9-pentaene. The patent document CN1509174 discloses the tartrate salt of 5,8,14-triazatetracyclo[10.3.1.0(2,11).0(4,9)]-hexadeca-2(11),3,5,7,9-pentaene. The patent document CN1589148 discloses the succinic acid salts of 5,8,14-triazatetracyclo[10.3.1.0(2,11).0(4,9)]-hexadeca-2(11),3,5,7,9-pentaene and pharmaceutical compositions thereof. These patent documents all disclose such a chemical structure with triazatetracyclo.

Through careful research, the inventor has unexpectedly developed a simple, feasible and economic method of preparing a novel compound of triazabicyclo[3,2,1]octane structure using 5-methyltetrahydrofolate as the raw material. This compound has a significant effect on inhibiting T lymphocyte proliferation.

## SUMMARY OF THE INVENTION

The first object of the present invention is to provide a novel compound of triazabicyclo[3,2,1]octane and characterize its structure. The chemical name of the compound is [4-(2-amino-10-methyl-4-oxo-6,7,8,9-tetrahydro-4a,7-imine-pyrimido[4,5-b][1,4]diazepine-5(4H)-yl)benzoyl]-glutamic acid, hereinafter referred to as JK12A. The second object of the present invention is to provide a crystal form of the above compound JK12A.



20 or a stereomer of the compound JK12A.

The present invention proposes the crystal of the compound JK12A.

The present invention proposes a pharmaceutically acceptable salt of the compound JK12A or a stereomer of the salt, wherein the salt is a crystallized salt.

The present invention also provides the X-ray diffraction pattern of the crystal form I of the compound JK12A with Cu-K $\alpha$  radiation, and with diffraction peaks at  $2\theta$  angle expressed in terms of degrees at  $13.3\pm0.2$ ,  $14.0\pm0.2$ ,  $16.9\pm0.2$ ,  $19.1\pm0.2$ ,  $24.4\pm0.2$  and  $27.6\pm0.2$ . Furthermore, the present invention also provides the X-ray diffraction pattern of the crystal form I of the compound JK12A with Cu-K $\alpha$  radiation, having diffraction peaks at  $2\theta$  angle expressed in terms of degrees at 13.3, 14.0, 16.9, 19.1, 24.4 and 27.6. The X-ray diffraction pattern of the crystal form I of the compound JK12A is shown in FIG. 11.

The present invention also provides the X-ray diffraction pattern of the crystal form II of the compound JK12A with Cu-K $\alpha$  radiation, and with diffraction peaks at  $2\theta$  angle expressed in terms of degrees at  $6.8\pm0.2$ ,  $12.2\pm0.2$ ,  $13.7\pm0.2$ ,  $15.9\pm0.2$ ,  $18.4\pm0.2$  and  $23.0\pm0.2$ .

Furthermore, the present invention also provides the X-ray diffraction pattern of the crystal form II of the compound JK12A with Cu-K $\alpha$  radiation, having diffraction peaks at  $2\theta$  angle expressed in terms of degrees at 6.8, 12.2, 13.7, 15.9, 18.4 and 23.0. The further X-ray diffraction pattern of the crystal form II of the compound JK12A is shown in FIG. 12.

The present invention provides a preparation method of the compound JK12A, comprising the process of oxidizing 5-methyltetrahydrofolate.

The present invention provides a preparation method of the crystal form I of the compound JK12A, comprising the following steps:

- Adding the 5-methyltetrahydrofolate into polar medium;
- Regulating the pH with alkali to 6~8;
- Adding an oxidizing agent with stirring;
- Regulating the pH with acid to 3~5;
- Crystallization.

The present invention also provides a preparation method of the crystal form II of the compound JK12A, comprising crystallization of the compound JK12A in polar medium through ultrasonication at pH $\geq$ 3. The polar medium can be water or a mixture of water and a polar water-miscible organic solvent.

Furthermore, the present invention provides a preparation method of the crystal form II of the compound JK12A, comprising the following steps:

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- a) Adding the compound JK12A into polar medium;
- b) Regulating the pH with alkali to 6~10, until the solid is dissolved;
- c) Crystallization through ultrasonication and regulating the pH with acid to 3~6. Purity of the crystal form I and II of the compound JK12A prepared from the above method can reach above 98.0%.

The present invention also provides a method for converting the compound JK12A to 5-methyltetrahydrofolate comprising reducing the compound JK12A to 5-methyltetrahydrofolate.

The present invention also provides a method for converting the compound JK12A to 5-methyltetrahydrofolate. An embodiment of the conversion method comprises dissolving the compound JK12A in water in the presence of alkali, then reacting with a reducing agent to obtain 5-methyltetrahydrofolate.

The present invention also provides applications of the compound JK12A such as for preparing drugs, and serving as an active ingredient in medications or food additives.

#### BRIEF DESCRIPTION OF THE DRAWINGS

- FIG. 1: UV spectrum of JK12A;  
 FIG. 2: IR spectrum of JK12A;  
 FIG. 3: High resolution mass spectrum of JK12A;  
 FIG. 4: <sup>1</sup>H-NMR spectrum of JK12A;  
 FIG. 5: <sup>13</sup>C-NMR spectrum of JK12A;  
 FIG. 6: DEPT135-NMR spectrum of JK12A;  
 FIG. 7: <sup>1</sup>H-<sup>1</sup>H COSY-NMR spectrum of JK12A;  
 FIG. 8: <sup>1</sup>H-<sup>1</sup>H NOESY-NMR spectrum of JK12A;  
 FIG. 9: HSQC-NMR spectrum of JK12A;  
 FIG. 10: HMBC-NMR spectrum of JK12A;  
 FIG. 11: X-ray diffraction pattern of the crystal form I of JK12A;  
 FIG. 12: X-ray diffraction pattern of the crystal form II of JK12A.

#### DETAILED DESCRIPTION OF THE INVENTION

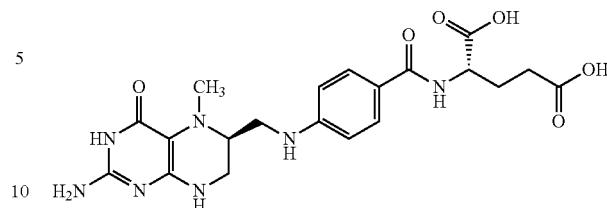
In order to better understand the technical scheme of the present invention, a detailed description of the preferred embodiments is presented to further illustrate the technical scheme of the present invention, but is not intended to restrict the present invention.

The compound JK12A referred to in the present invention can be characterized by various means.

The compound JK12A, is characterized in that it is synthesized through oxidation of 5-methyltetrahydrofolate. Where, the chemical name of the 5-methyltetrahydrofolate is N-[4-[(2-amino-1,4,5,6,7,8,-hexahydro-4-oxo-5-methyl-6-pteridiny)methyl]amino]benzoyl]-L-glutamic acid. Please refer to patent documents CN1122337A, CN92100247.5, CN200910134474.4, CN200610041541.4, CN00108884.X and GR3029552T3 for the characteristics of 5-methyltetrahydrofolate, the technical disclosures of which are incorporated herein by reference in their entireties. Therefore, the present invention proposes the following structural formula for 5-methyltetrahydrofolate:

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II



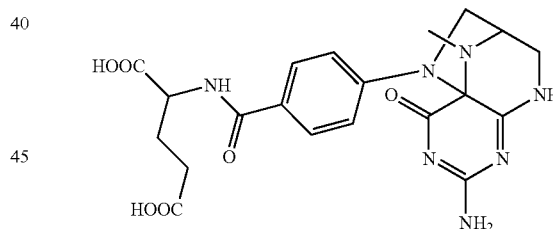
In the invention, 5-methyltetrahydrofolate is oxidized with an oxidizing agent. As described below, the oxidizing agent may be air, or oxygen, or hydrogen peroxide.

The compound JK12A, is prepared with the following method:

- a) Dissolving 5-methyltetrahydrofolate in polar medium in the presence of alkali;
- b) Generating the compound JK12A through reaction with the oxidizing agent;
- c) Separating the compound JK12A from solution with acid,

Wherein, nitrogen or inert gas protection may be used in step a); nitrogen is preferred; 5-methyltetrahydrofolate solution is regulated with alkali to pH value of 6~8, until the solid is dissolved. In step b), high active surfactant may be used as a catalyst and/or ultrasonication may be used; the oxidizing agent is preferably air, or oxygen, or hydrogen peroxide. In step c), the reaction solution is regulated to pH 3~5 preferably with acid. After precipitation, the solid is filtered, washed and dried. The preparation process is carried out under normal pressure and at normal temperature. The duration of each step is determined, as necessary, according to the amount of the raw material (5-methyltetrahydrofolate), alkali and acid, etc. The compound JK12A, also having the molecular structure as follows:

I



The present invention also relates to a variety of stereomers of the compound JK12A, such as [4-((4aS, 7R)-2-amino-10-methyl-4-oxo-6,7,8,9-tetrahydro-4a,7-cycloimino-pyrimido[4,5-b][1,4]diazepine-5(4H)-yl)benzoyl]-L-glutamic acid, [4-((4aS, 7S)-2-amino-10-methyl-4-oxo-6,7,8,9-tetrahydro-4a,7-cycloimino-pyrimido[4,5-b][1,4]diazepine-5(4H)-yl)benzoyl]-L-glutamic acid, [4-((4aR, 7S)-2-amino-10-methyl-4-oxo-6,7,8,9-tetrahydro-4a,7-cycloimino-pyrimido[4,5-b][1,4]diazepine-5(4H)-yl)benzoyl]-L-glutamic acid, [4-((4aR, 7R)-2-amino-10-methyl-4-oxo-6,7,8,9-tetrahydro-4a,7-cycloimino-pyrimido[4,5-b][1,4]diazepine-5(4H)-yl)benzoyl]-L-glutamic acid, etc.

JK12A in the present invention may be characterized by one or more of the following means:

UV spectrum with maximum absorption peaks at about 203.0 nm, 252.5 nm and 295.5 nm;

IR spectrum with peaks at about 3383 cm<sup>-1</sup>, 2885 cm<sup>-1</sup>, 1608 cm<sup>-1</sup>, 1558 cm<sup>-1</sup>, 1508 cm<sup>-1</sup>, 1421 and 1321 cm<sup>-1</sup>;

<sup>1</sup>HNMR spectrum with chemical shift of hydrogen at about 1.89, 2.04, 2.31, 3.43, 3.49, 3.86, 3.90, 3.94, 4.21, 6.48 and 7.62;

<sup>13</sup>CNMR spectrum with chemical shift of carbon at about 28.37, 31.26, 34.25, 45.18, 55.04, 55.16, 55.93, 68.80, 112.23, 129.17, 146.36, 165.58, 169.50, 171.74, 176.65, 179.29 and 182.49;

HR-MS (ESI-) spectrum with a peak at about  $m/z=456.163761$  ( $[M-H]^-$ ); indicating that the molecular weight of JK12A is 457, and its elementary composition is  $C_{20}H_{23}N_7O_6$ .

The present invention also relates to the crystal of the compound JK12A. Through experimentation, the inventor has found two crystal forms.

The preparation method of the crystal form I of the compound JK12A crystal, comprising the following steps:

- Adding the 5-methyltetrahydrofolate into polar medium;
- Regulating the pH with alkali to 6~8;
- Adding an oxidizing agent with stirring;
- Regulating the pH with acid to 3~5;
- Crystallization.

Preferably, in step a), the polar medium is water or a mixture of water and a water-miscible organic solvent. This method does not have specific requirements for the amount of the polar medium. The 5-methyltetrahydrofolate is selected from (6S)-5-methyltetrahydrofolate, (6R)-5-methyltetrahydrofolate and (6R, S)-5-methyltetrahydrofolate, and is preferably (6S)-5-methyltetrahydrofolate.

In step b), the alkali is an organic alkali or inorganic alkali that can form a salt with 5-methyltetrahydrofolate, wherein, the inorganic alkali is selected from alkali of alkalis or alkaline earth, carbonate and bicarbonate; the organic alkali is selected from ammonia, amine, pyridine and piperazine; preferably potassium hydroxide, sodium hydroxide, calcium hydroxide, magnesium hydroxide, potassium carbonate, sodium carbonate, potassium bicarbonate, sodium bicarbonate, ammonia, monomethylamine, 4-dimethylpyridine, and piperazine. The alkali may be directly added, or added in the form of solution (aqueous solution for instance). The pH value of the solution is generally regulated with alkali generally to 6.0~8.0, preferably 7.0~7.5.

In step c), the oxidizing agent is air, or oxygen, or hydrogen peroxide.

Preferably, a step of adding high active surfactant before the step c) can be included. The high active surfactant is selected from active carbon, active silica gel and active aluminum oxide, and is preferably active carbon. Wherein, the use level of the high active surfactant is 0.05~10 times as much as the mass of 5-methyltetrahydrofolate, preferably 0.5~2 times, and more preferably 0.5~1 times. More preferably, the high active surfactant is added between the step b) and step c), that is, the oxidizing agent is added immediately after adding the high active surfactant. The stirring is preferably terminated after the reaction of the raw material 5-methyltetrahydrofolate is over, as indicated by HPLC, lasting for generally more than 10 hours, and preferably 12~24 hours.

In step d), the acid is organic acid or inorganic acid. Preferably, the inorganic acid is selected from hydrochloric acid, sulfuric acid and hydrobromic acid; the organic acid is selected from formic acid, acetic acid and phenylmethanesulfonic acid. The pH value of the solution is preferably regulated with acid to 4~5. It is understandable that after crystallization, steps such as filtration, washing, drying and the like can be carried out.

The main peaks of the X-ray diffraction pattern in terms of  $2\theta$  and distance  $d$  measured through  $CuK\alpha$  radiation (within the error range) of crystal form I are listed as follows:

TABLE 1

Characteristic peaks of the X-ray diffraction pattern of the crystal form I	
$2\theta$ ( $\pm 0.2$ )	$d$ ( $\text{\AA}$ ) ( $\pm 0.2$ )
13.3	6.7
14.0	6.3
16.9	5.2
19.1	4.6
24.4	3.6
27.6	3.2

The crystal form II of the compound JK12A, wherein, the compound JK12A is crystallized with the aid of ultrasonication in polar medium at  $pH \geq 3$ . Preferably, the polar medium is water or a mixture of water and a polar water-miscible organic solvent. Furthermore, the preparation method of the crystal form II of the compound JK12A, comprises the following steps:

- Adding the compound JK12A into polar medium;
- Regulating the pH with alkali to 6~10, until the solid is dissolved;
- Crystallization through ultrasonication and regulating the pH with acid to 3~6.

In step a), the compound JK12A may be amorphous or crystal form I. The polar medium is water or a mixture of water and a polar water-miscible organic solvent. In step b), the alkali is organic alkali or inorganic alkali. Preferably, the inorganic alkali is selected from potassium hydroxide, sodium hydroxide, calcium hydroxide, magnesium hydroxide, potassium carbonate, sodium carbonate, potassium bicarbonate and sodium bicarbonate; the organic alkali is selected from ammonia, monomethylamine, 4-dimethylpyridine and piperazine. The alkali may be directly added, or added in the form of solution (aqueous solution for instance). The pH of the solution is regulated with the alkali preferably to 7.0~8.0, and more preferably 7.0~7.5.

In step c), the acid is organic acid or inorganic acid. Preferably, the inorganic acid is selected from hydrochloric acid, sulfuric acid and hydrobromic acid; the organic acid is selected from formic acid, acetic acid and phenylmethanesulfonic acid. A pH value of the solution is preferably regulated with acid to 3~4. In the step b), ultrasonication may be used to facilitate fast dissolution of the compound JK12A. In the step c), ultrasonication is used to facilitate formation of the crystal form II. The duration of ultrasonication is determined as necessary, and may stop after enough solid precipitates.

The main peaks of the X-ray diffraction pattern in terms of  $2\theta$  and distance  $d$  measured through  $CuK\alpha$  radiation (within the error range) of crystal form II are listed as follows:

TABLE 2

Characteristic peak of the X-ray diffraction pattern of the crystal form II	
$2\theta$ ( $\pm 0.2$ )	$d$ ( $\text{\AA}$ ) ( $\pm 0.2$ )
6.8	13.0
12.2	7.3
13.7	6.5
15.9	5.6
18.4	4.8
23.0	3.8

The present invention also relates to a method for converting the compound JK12A to 5-methyltetrahydrofolate, comprising reducing the compound JK12A to 5-methyltetrahydrofolate. The method may also be used for purification of

5-methyltetrahydrofolate. Crude product of 5-methyltetrahydrofolate is oxidized to form JK12A, which is reduced to 5-methyltetrahydrofolate after crystallization. The 5-methyltetrahydrofolate is obtained with significantly improved chemical purity and optical purity. Therefore, one of the applications of the compound JK12A of the present invention is to prepare and purify 5-methyltetrahydrofolate.

The present invention relates to a preparation method of 5-methyltetrahydrofolate, wherein, the compound JK12A is reduced to 5-methyltetrahydrofolate.

Preferably, the preparation method of 5-methyltetrahydrofolate comprises: first dissolving the compound JK12A in water in the presence alkali, then adding the reducing agent, and obtaining 5-methyltetrahydrofolate through separation. Wherein, the reducing agent is preferably borohydride, or reducing gas, or sulphydryl compound. The borohydride is selected from sodium borohydride, potassium borohydride and potassium tri-tert-butylborohydride; the reducing gas is selected from H<sub>2</sub> and borane; the sulphydryl compound is selected from mercaptoethanol, cysteine and mesna. The separation step refers to separating 5-methyltetrahydrofolate from solution and is a prior art that may be referred to in relevant reference documents cited hereinbefore.

The alkali is an inorganic alkali or organic alkali that can form a salt with 5-methyltetrahydrofolate. The inorganic alkali is selected from alkali of alkalis or alkaline earth, carbonate and bicarbonate; the organic alkali is selected from ammonia, amine, pyridine and piperazine; preferably: potassium hydroxide, sodium hydroxide, calcium hydroxide, magnesium hydroxide, potassium carbonate, sodium carbonate, potassium bicarbonate, sodium bicarbonate, ammonia, monomethylamine, 4-dimethylpyridine and piperazine. The alkali may be directly added, or added in the form of solution (aqueous solution for instance). The present invention also relates to an acceptable salt of the compound JK12A, which is selected from alkali metal salt or alkaline earth metal salt, preferably potassium salt, sodium salt, calcium salt, magnesium salt, barium salt and strontium salt, and more preferably calcium salt.

The present invention also relates to a preparation method of the calcium salt of the compound JK12A, comprising the following steps:

- Adding the compound JK12A into polar medium;
- Regulating the pH with alkali to 7~8, until the solid is dissolved;
- Adding calcium chloride;
- Solid precipitation through ultrasonication, then filtration, washing and drying;

In step a), the polar medium is water or a mixture of water and a polar water-soluble organic solvent, preferably water. In step b), the alkali is an organic alkali or inorganic alkali. Preferably, the inorganic alkali is selected from potassium hydroxide, sodium hydroxide, calcium hydroxide, magnesium hydroxide, potassium carbonate, sodium carbonate, potassium bicarbonate and sodium bicarbonate; the organic alkali is selected from ammonia, monomethylamine, 4-dimethylpyridine and piperazine.

The compound JK12A is used as an active ingredient of drugs in drug preparation. The immune bioactivity experiment in Example 16 shows that the compound JK12A can be used to prepare drugs, and may also be used to prepare food additives.

The pharmaceutical preparations or compositions in the present invention contain the above compound JK12A or salt thereof. The compound JK12A or salt thereof prepared with the method in the present invention is ideal for pharmaceutical preparations. The pharmaceutical preparations in the

present invention may contain one or more excipients besides active ingredients. The excipients are added to pharmaceutical preparations for various purposes. The above preparations may be prepared with the prior art in this field.

The compound JK12A prepared in the present invention is analyzed as follows:

#### 1. Ultraviolet (UV) Analysis:

Instrument model: TU-1901, Beijing Purkinje General Instrument Co., Ltd, TU-1901

Sample concentration: 0.02366 mg/mL

Solvent: Methanol

Scan range: 200.00-900.00 nm

Scanning interval: 0.50 nm

Test result: UV spectrum of this product shows that there are maximum absorption at 203.0 nm, 252.5 nm and 295.5 nm, respectively corresponding to absorption of —C=O and K band of the benzene ring. UV absorption spectrum is shown in FIG. 1.

#### 2. IR Analysis:

Instrument model: Shimadzu, FTIR Presitage 21

Test conditions: KBr tableting method

Test result: Main absorption peaks and corresponding groups are shown in Table 1. The IR absorption spectrum is shown in FIG. 2.

TABLE 3

Main IR absorption peaks of the compound JK12A			
Absorption peak (cm <sup>-1</sup> )	Vibration	Corresponding group	Absorption peak intensity
3383	$\nu\text{NH}_2, \nu\text{OH}, \nu\text{NH}$	—NH <sub>2</sub> —OH—NH	s
2885	$\nu\text{CH}$	—CH—, —CH <sub>2</sub>	w
1608	$\nu\text{C=O}$	—C=O	s
1558	$\nu\text{C=N}$	—C=N	s
1508, 1421	$\nu\text{C=C}$	—C=C	s
1321	$\nu\text{C—N}$	—C—N	m

#### 3. High Resolution Mass Spectrometry (HR-MS):

Instrument model: Bruker Daltonics, Inc., APEX III 7.0TESLAFTMS

Test result: Elementary composition of this product is measured using high resolution mass spectrometry. A peak at 456.16376 is obtained through detection in the anionic mode of ESI-MS/MS, showing that elementary composition of this product is C<sub>20</sub>H<sub>23</sub>N<sub>7</sub>O<sub>6</sub>. Data list is shown in Table 2, and the mass spectrum is shown in FIG. 3.

TABLE 4

High resolution elementary composition analysis data list				
Measured value	Theoretical value	Deviation (mDa)	Precision (ppm)	Elementary composition
456.16376	456.16371	-0.05	-6.01	C <sub>20</sub> H <sub>23</sub> N <sub>7</sub> O <sub>6</sub>

#### 4. NMR Analysis

Instrument model: Bruker, AVANCE III500 MHz UltraShield-Plus™ digital NMR spectrometer

Solvent: D<sub>2</sub>O

Test items:

<sup>1</sup>H-NMR, <sup>13</sup>C-NMR, DEPT135, <sup>1</sup>H-<sup>1</sup>H COSY, <sup>1</sup>H-<sup>1</sup>H NOESY, HSQC, HMBC

Test result: NMR spectrum is shown in FIGS. 4-10. Corresponding groups are listed in Table 3 and Table 4.

TABLE 5

Chemical shift of <sup>1</sup> H					
Chemical shift(δ(ppm))	Diversity	Proton number	Corresponding group	<sup>1</sup> H- <sup>1</sup> H COSY Relative absorption	<sup>1</sup> H- <sup>1</sup> H NOESY Relative absorption
7.62	d, J = 8.8 Hz	2H	H-16,18	H-15,19	H-16,18
6.48	d, J = 8.8 Hz	2H	H-15,19	H-16,18	H-15,19,9,9'
4.21	dd, J = 9.0, 4.6 Hz	1H	H-22	H-23,23'	H-23,23',24
3.94	m	1H	H-6	H-7',9'	
3.90	m	1H	H-7	H-7',6	
3.86	m	1H	H-9	H-9',6	
3.49	d, J = 8.4 Hz	1H	H-9'	H-9,6	H-9,6
3.43	d, J = 14.1 Hz	1H	H-7'	H-7,6	H-7,6
2.31	s	3H	H-11		H-6
2.22	t, J = 7.9 Hz	2H	H-24	H-23,23'	H-22,23,23'
2.04-2.11	m	1H	H-23	H-23',24,22	H-23',24,22
1.89-1.97	m	1H	H-23'	H-23,24,22	H-23,24,22

TABLE 6

Chemical shift of <sup>13</sup> C					
Chemical shift δ ppm	Carbon number	Corresponding group	DEPT135	HSQC	HMBC
182.49	1	C-25	C	—	H-23,23',24
179.29	1	C-26	C	—	H-22,23
176.65	1	C-4	C	—	
171.74	1	C-13	C	—	H-7
169.50	1	C-20	C	—	H-16,19,22
165.58	1	C-2	C	—	—
146.36	1	C-14	C	—	H-16,18
129.17	2	C-16,18	CH	H-16,18	
123.15	1	C-17	C	—	H-15,19
112.23	2	C-15,19	CH	H-15,19	
68.80	1	C-12	C	—	H-6,9',11
55.93	1	C-22	CH	H-22	H-23,24
55.16	1	C-9	CH2	H-9,9'	H-7
55.04	1	C-6	CH	H-6	H-11
45.18	1	C-7	CH2	H-7,7'	H-9
34.25	1	C-24	CH2	H-24	H-22,23'
31.26	1	C-11	CH3	H-11	
28.37	1	C-23	CH2	H-23,23'	H-22,24

## Example 1

## Preparation of the Crystal Form I of JK12A

Under nitrogen protection, 5 g of 5-methyltetrahydrofolate was dissolved in 50 g of water in a reaction flask with stirring, and then regulated with saturated sodium carbonate solution to pH 7.5. After the solid was completely dissolved, 2.5 g of active carbon was added, and then sealed in an oxygen balloon overnight. After HPLC showed that the reaction of raw materials was completed, the system was filtered, and the filtrate was regulated with 50% acetic acid to pH 4.8 for crystallization. After filtration, the filter cake was respectively washed with ethanol and acetone, and then 3.0 g of yellow solid was obtained through vacuum drying with purity of 87.53%.

## Example 2

## Preparation of the Crystal Form I of JK12A

Under nitrogen protection, 5 g of 5-methyltetrahydrofolate was dissolved in 40 g of water in a reaction flask with stirring, and then regulated with 90% monomethylamine solution to pH 7.0. After the solid was completely dissolved, 2.5 g of

active carbon was added, and then sealed in an oxygen balloon overnight. After HPLC showed that the reaction of raw materials was completed, the system was filtered, and the filtrate was regulated with 10% hydrochloric acid to pH 3.0 for crystallization. After filtration, the filter cake was respectively washed with ethanol and acetone, and then 2.5 g of yellow solid was obtained through vacuum drying with chemical purity of 97.37%.

## Example 3

## Preparation of the Crystal Form I of JK12A

Under nitrogen protection, 5 g of 5-methyltetrahydrofolate was dissolved in 40 g of water in a reaction flask with stirring, and then regulated with 10% sodium hydroxide solution to pH 7.5. After the solid was completely dissolved, 2.5 g of active carbon was added, and then kept open overnight. After HPLC showed that the reaction of raw materials was completed, the system was filtered, and the filtrate was regulated with 50% acetic acid to pH 4.2 for crystallization. After filtration, the filter cake was respectively washed with ethanol and acetone, and then 2.3 g of yellow solid was obtained through vacuum drying with chemical purity of 95.00%.

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## Example 4

## Preparation of the Crystal Form I of JK12A

Under nitrogen protection, 73.3 g of 5-methyltetrahydrofolate was dissolved in 580 g of water in a reaction flask with stirring, and then regulated with 10% sodium hydroxide solution to pH 7.2. After the solid was completely dissolved, 40 g of active carbon was added, and then sealed in an oxygen balloon overnight. After HPLC showed that the reaction of raw materials was completed, the system was filtered, and the filtrate was regulated with 50% acetic acid to pH 4.0 for crystallization. After filtration, the filter cake was respectively washed with ethanol and acetone, and then 47.8 g of yellow solid was obtained through vacuum drying with chemical purity of 96.20%.

## Example 5

## Preparation of the Crystal Form I of JK12A

Under nitrogen protection, 10 g of 5-methyltetrahydrofolate was dissolved in 80 g of water in a reaction flask with stirring, and then regulated with 10% sodium hydroxide solution to pH 7.3. After the solid was completely dissolved, 5 g of active carbon was added, and then kept open overnight. After HPLC showed that the reaction of raw materials was completed, the system was filtered, and the filtrate was regulated with 50% acetic acid to pH 4.0 for crystallization. After filtration, the filter cake was respectively washed with ethanol and acetone, and then 6.0 g of yellow solid JK12A was obtained through vacuum drying with chemical purity of 99.42%.

## Example 6

## Preparation of the Crystal Form I of JK12A

Under nitrogen protection, 5 g of 5-methyltetrahydrofolate was dissolved in 40 g of water in a reaction flask with stirring, and then regulated with 10% sodium hydroxide solution to pH 7.5. After the solid was completely dissolved, 5 g of active carbon was added, and then sealed in an oxygen balloon overnight. After HPLC showed that the reaction of raw materials was completed, the system was filtered, and the filtrate was regulated with 50% acetic acid to pH 4.8 for crystallization. After filtration, the filter cake was respectively washed with ethanol and acetone, and then 2.7 g of yellow solid JK12A was obtained through vacuum drying with chemical purity of 99.60%.

## Example 7

## Preparation of the Crystal Form I of JK12A

Under nitrogen protection, 5 g of 5-methyltetrahydrofolate was dissolved in 50 g of water in a reaction flask with stirring, and then regulated with 10% sodium hydroxide solution to pH 7.2. After the solid was completely dissolved, 4 g of active silica gel was added, and then sealed in an oxygen balloon overnight. After HPLC showed that the reaction of raw materials was completed, the system was filtered, and the filtrate was regulated with 50% acetic acid to pH 4.5 for crystallization. After filtration, the filter cake was respectively washed with ethanol and acetone, and then 2.3 g of yellow solid JK12A was obtained through vacuum drying with chemical purity of 98.41%.

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## Example 8

## Preparation of the Crystal Form II of JK12A

2.0 g of JK12A was dissolved in 22 g of water in an ice water bath. 10% sodium hydroxide was added dropwise with stirring to regulate the solution to pH 6.7. After the solid was completely dissolved, the reaction solution was transferred to an ultrasonic device, and 50% acetic acid was added dropwise to regulate pH value of the solution to 5.2. 30 min later, the system was filtered, the filter cake was respectively washed with water, ethanol and acetone, and then 1.0 g of yellow solid JK12A was obtained through vacuum drying with chemical purity of 98.2%.

## Example 9

## Preparation of the Crystal Form II of JK12A

5.0 g of JK12A was dissolved in 50 g of water in an ice water bath. 10% sodium hydroxide was added dropwise with stirring to regulate the solution to pH 7.5. After the solid was completely dissolved, the reaction solution was transferred to an ultrasonic device, and 50% acetic acid was added dropwise to regulate pH value of the solution to 4.0. 30 min later, the system was filtered, the filter cake was respectively washed with water, ethanol and acetone, and then 2.2 g of yellow solid JK12A was obtained through vacuum drying with chemical purity of 98.5%.

## Example 10

## Preparation of the Crystal Form II of JK12A

8.0 g of JK12A was dissolved in 120 g of water in an ice water bath. 10% sodium hydroxide was added dropwise with stirring to regulate the solution to pH 8.0. After the solid was completely dissolved, the reaction solution was transferred to an ultrasonic device, and 50% acetic acid was added dropwise to regulate pH value of the solution to 5.0. 30 min later, the system was filtered, the filter cake was respectively washed with water, ethanol and acetone, and then 5.2 g of yellow solid JK12A was obtained through vacuum drying with chemical purity of 98.7%.

## Example 11

## Preparation of the Calcium Salt of JK12A

4.0 g of JK12A was dissolved in 20 g of water with stirring at room temperature. 10% sodium hydroxide was added to regulate the solution to pH 7.0. After the solid was completely dissolved, the reaction solution was cooled to 10° C. 4.0 g of 50% calcium chloride solution was added with stirring for 10 min. Then 25 mL of ethanol was added. After kept in an ultrasonic device for 30 min, the system was filtered, the filter cake was respectively washed with ethanol and acetone, and then 3.5 g of calcium salt of JK12A was obtained through vacuum drying with chemical purity of 97.6%.

## Example 12

## Reduction of JK12A

3.0 g of JK12A (purity 96.64%) was dissolved in 60 g of water, and then regulated with 10% sodium hydroxide to pH 7.0 with stirring. After the solid was completely dissolved, 2

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g of  $\text{KBH}_4$  was slowly added with further stirring for 1 hour. Results indicate that the content of 5-methyltetrahydrofolate was 71.26% in the reaction solution.

## Example 13

## Reduction of JK12A

3 g of JK12A (purity 96.64%) was dissolved in 60 g of water, and then regulated with 10% sodium hydroxide to pH 7.2 with stirring. After the solid was completely dissolved, 2 g of  $\text{NaBH}_4$  was slowly added with further stirring for 1.5 hours. Results indicate that the content of 5-methyltetrahydrofolate was 79.32% in the reaction solution.

## Example 14

## Reduction of JK12A

10 g of JK12A (purity 96.64%) was dissolved in 150 g of water, and then regulated with 10% sodium hydroxide to pH 7.0 with stirring. After the solid was completely dissolved, 1.0 g of Pd/C was added, and fully stirred. After  $\text{H}_2$  was insufflated, the system was pressurized to 0.2 MPa, and stirred for 2 h. Results indicate that the content of 5-methyltetrahydrofolate was 70.32% in the reaction solution.

## Example 15

## Purification of 5-methyltetrahydrofolate

10 g of 5-methyltetrahydrofolate (chemical purity 82%, optical purity 90%) was dissolved in 1000 g of water, and then regulated with 10% sodium hydroxide to pH 7.0 with stirring. After the solid was completely dissolved, 5 g of active carbon was added, and sealed in an oxygen balloon. After HPLC showed that the reaction of raw materials was completed, the system was filtered, and the filtrate was regulated with 10% hydrochloric acid to pH 3.0 for crystallization. After filtration, the filter cake was respectively washed with ethanol and acetone, and then 5.2 g of yellow solid JK12A was obtained through vacuum drying with chemical purity of 97.8%. The solid was added into 80 g of water, and then regulated with 10% sodium hydroxide to pH 7.0 with stirring. 12 g of sodium borohydride was slowly added. 4 hours later, the solution was regulated with 10% hydrochloric acid to pH 3.0 for crystallization. After filtration, the filter cake was respectively

## 16

washed with ethanol and acetone, and then 2.9 g of 5-methyltetrahydrofolate was obtained through vacuum drying with chemical purity of 98.1% and optical purity of 96%.

## Example 16

## Immune Bioactivity

## Experimental Method

## Preparation of Murine Splenic Lymphocytes

After mice were killed through spine dislocation, their spleen was taken aseptically to prepare a single cell suspension. Redblood cells were removed from red blood cell lysis buffer, and the cell concentration was regulated.

Effect of the compound on the activity of murine splenic lymphocytes was detected with CCK-8 method:

Murine splenic lymphocyte suspension was inoculated in 96-well plates with  $5 \times 10^5$ /well.

Different concentrations of the compound were added. Corresponding solvent control and nutrient solution background control were also arranged. The total volume was 200  $\mu\text{L}$ . The suspension was cultivated in an incubator with 5%  $\text{CO}_2$  at 37° C. for 48 hours. 8-10 hours before the cultivation was completed, CCK-8 solution was added. On completion of the cultivation, the OD value was measured with an ELIASA at 450 nm (reference 650 nm).

Effect of the compound on the proliferation function of murine splenic lymphocytes was detected with  $^3\text{H}$ -TdR incorporation method:

Murine splenic lymphocyte suspension was inoculated in 96-well plates with  $5 \times 10^5$ /well.

ConA (final concentration: 5  $\mu\text{g}/\text{ml}$ ) and different concentrations of the compound were added. Corresponding control well without ConA and control well without drugs were also arranged. The suspension was cultivated in an incubator with 5%  $\text{CO}_2$  at 37° C. for 48 hours. 8 hours before the cultivation was completed, 25  $\mu\text{L}$  of  $^3\text{H}$ -TdR (10  $\mu\text{Ci}/\text{ml}$ ) was added to each well. The suspension was further cultivated until the experiment was completed. Cells were collected with a cell collector onto a glass fiber membrane. After adding scintillation solution, the count of  $^3\text{H}$ -TdR incorporated into cellular DNA was obtained from a Beta counter (MicroBeta Trilux, PerkinElmer). The cell proliferation was expressed in terms of CPM.

TABLE 7

Experimental results								
	Measured conc.				T lymphocyte	Tcell proliferation		
		Average OD	SD	Cell survival rate	ConA stimulation	Evaluation on comprehensive activity		
					Average CPM	SD	enhanced/inhibitedpercentage	
Control		0.122	0.003	Cell control Stimulation control	43977	8000		
JK12A	100.000	0.089	0.002	73%				
	40.000	0.109	0.006	89%	43537	4110		-1%
	16.0	0.113	0.007	92%	36061	241		-18%
	6.4	0.103	0.007	84%	30784	3903		-30%
	2.56	0.076	0.008	62%	25507	10004		-42%
	1.024	0.073	0.014	59%	17590	8005		-60%

TABLE 7-continued

0.41	0.052	0.015	75%	14073	10299	-68%
0.164				40459	7501	-8%

According to the preliminary screening results, the compound JK12A has significant effect on inhibiting murine T lymphocyte proliferation (at 1,024 and 0.41 uM).

## Example 17

## X-Ray Diffraction Pattern Conditions and Data of the Crystal Form I of JK12A

Instrument model: Bruker D8 advance XRD

Diffracted ray: CuK $\alpha$  radiation (40 kV, 40 mA)

Scan rate: 8°/min (2 $\theta$  value)

Scan range: 5°–45° (2 $\theta$  value)

Peak Search Report (41 Peaks, Max P/N=25.4)

PEAK: 27-pts/ParaBolic Filter, Threshold=3.0, Cut-off=0.1%, BG=3/1.0, Peak-Top=Summit

TABLE 8

X-ray diffraction pattern data of the crystal form I of JK12A								
#	2 $\theta$	d(Å)	BG	Height	I %	Area	I %	FWHM
1	7.759	11.3855	515	711	21.6	14304	12.2	0.342
2	12.001	7.3686	811	1923	58.4	36858	31.4	0.326
3	13.280	6.6614	882	1624	49.3	63703	54.3	0.667
4	13.641	6.4863	1170	2081	63.2	92889	79.1	0.759
5	14.040	6.3024	1509	1831	55.6	41910	35.7	0.389
6	15.121	5.8542	1296	1328	40.4	26130	22.3	0.334
7	15.821	5.5971	1162	1426	43.3	19410	16.5	0.231
8	16.939	5.2298	969	1637	49.7	32946	28.1	0.342
9	17.520	5.0578	1118	715	21.7	10094	8.6	0.240
10	19.119	4.6382	917	3291	100.0	117380	100.0	0.606
11	19.640	4.5163	821	2469	75.0	45052	38.4	0.310
12	20.293	4.3724	834	131	4.0	1110	0.9	0.144
13	21.180	4.1913	887	524	15.9	13519	11.5	0.439
14	22.023	4.0328	865	276	8.4	5088	4.3	0.313
15	22.941	3.8734	988	959	29.1	17399	14.8	0.308
16	24.020	3.7019	1361	1373	41.7	31757	27.1	0.393
17	24.440	3.6391	1188	2088	63.4	58657	50.0	0.478
18	25.042	3.5530	1445	444	13.5	7410	6.3	0.284
19	25.559	3.4822	1110	638	19.4	6104	5.2	0.163
20	26.718	3.3337	955	702	21.3	11858	10.1	0.287
21	27.581	3.2314	1010	1376	41.8	39313	33.5	0.486
22	28.039	3.1796	989	1111	33.8	39585	33.7	0.606
23	29.019	3.0745	941	833	25.3	11044	9.4	0.225
24	29.921	2.9838	828	1160	35.2	22209	18.9	0.325
25	30.919	2.8897	676	381	11.6	7114	6.1	0.317
26	32.319	2.7676	743	1000	30.4	31248	26.6	0.531
27	33.062	2.7072	876	153	4.6	888	0.8	0.099
28	33.499	2.6729	858	280	8.5	5549	4.7	0.337
29	33.880	2.6436	759	468	14.2	13836	11.8	0.503
30	34.338	2.6094	710	386	11.7	8649	7.4	0.381
31	35.818	2.5049	634	501	15.2	10222	8.7	0.347
32	36.700	2.4467	630	335	10.2	9973	8.5	0.506
33	37.980	2.3672	630	128	3.9	4291	3.7	0.570
34	38.296	2.3483	641	142	4.3	1751	1.5	0.210
35	38.941	2.3109	665	340	10.3	5087	4.3	0.254
36	39.476	2.2808	651	136	4.1	3806	3.2	0.476
37	40.444	2.2284	605	152	4.6	985	0.8	0.110
38	42.020	2.1484	445	216	6.6	8224	7.0	0.647
39	42.360	2.1320	452	169	5.1	6117	5.2	0.615
40	44.098	2.0519	494	166	5.0	4528	3.9	0.464
41	44.422	2.0377	537	172	5.2	3979	3.4	0.393

## Example 18

## X-Ray Diffraction Pattern Conditions and Data of the Crystal Form II of JK12A

Instrument model: Broker D8 advance XRD

Diffracted ray: CuK $\alpha$  radiation (40 kV, 40 mA)

Scan rate: 8°/min (2 $\theta$  value)

Scan range: 5°–45° (2 $\theta$  value)

Peak Search Report (45 Peaks, Max P/N=32.8)

PEAK: 21-pts/ParaBolic Filter, Threshold=3.0, Cut-off=0.1%, BG=3/1.0, Peak-Top=Summit

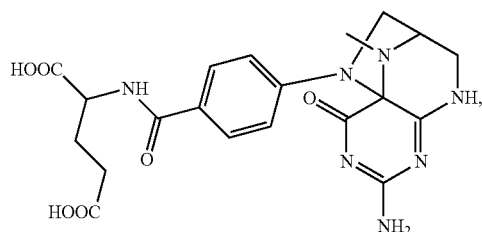
TABLE 9

X-ray diffraction pattern data of the crystal form II of JK12A								
#	2 $\theta$	d(Å)	BG	Height	I %	Area	I %	FWHM
1	6.802	12.9849	441	2177	43.6	38932	29.4	0.304
2	7.882	11.2075	458	98	2	548	0.4	0.095
3	9.054	9.7587	446	318	6.4	4551	3.4	0.243
4	12.159	7.2733	757	4722	94.5	91934	69.5	0.331
5	12.631	7.0024	906	511	10.2	3179	2.4	0.106
6	13.241	6.681	886	2183	43.7	75245	56.9	0.586
7	13.66	6.477	797	4995	100	132219	100	0.45
8	13.899	6.3661	798	2640	52.9	123894	93.7	0.798
9	14.903	5.9395	728	571	11.4	6392	4.8	0.19
10	15.938	5.556	700	3967	79.4	62015	46.9	0.266
11	16.761	5.285	659	827	16.6	14318	10.8	0.294
12	17.358	5.1047	664	1072	21.5	14176	10.7	0.225
13	18.36	4.8282	736	4076	81.6	64427	48.7	0.269
14	19.158	4.6289	485	2105	42.1	35665	27	0.288
15	19.581	4.5299	753	504	10.1	5465	4.1	0.184
16	21.079	4.2112	607	1678	33.6	32369	24.5	0.328
17	21.96	4.0441	620	1720	34.4	25073	19	0.248
18	23.019	3.8605	553	1857	37.2	25628	19.4	0.235
19	24.28	3.6627	763	765	15.3	14228	10.8	0.316
20	24.861	3.5785	916	1834	36.7	35340	26.7	0.328
21	26.001	3.4241	707	1953	39.1	29063	22	0.253
22	26.745	3.3305	635	1184	23.7	18539	14	0.266
23	27.721	3.2154	610	1411	28.2	30555	23.1	0.368
24	28.34	3.1466	578	866	17.3	14546	11	0.286
25	29.701	3.0054	664	468	9.4	6144	4.6	0.223
26	30.281	2.9491	666	2674	53.5	51357	38.8	0.327
27	31.836	2.8085	600	261	5.2	1807	1.4	0.118
28	32.239	2.7743	538	337	6.7	8170	6.2	0.412
29	32.643	2.7409	552	344	6.9	8454	6.4	0.418
30	32.918	2.7187	583	355	7.1	3694	2.8	0.177
31	33.52	2.6712	657	933	18.7	10292	7.8	0.188
32	34.12	2.6256	584	569	11.4	9227	7	0.276
33	34.72	2.5816	606	915	18.3	16472	12.5	0.306
34	35.684	2.514	493	472	9.4	7030	5.3	0.253
35	36.589	2.4539	495	213	4.3	2153	1.6	0.172
36	36.962	2.43	473	402	8	9635	7.3	0.407
37	37.523	2.3949	549	166	3.3	1503	1.1	0.154
38	39.041	2.3052	408	203	4.1	1347	1	0.113
39	39.557	2.2764	423	334	6.7	6005	4.5	0.306
40	40.596	2.2205	410	159	3.2	2271	1.7	0.243
41	41.123	2.1932	406	143	2.9	1150	0.9	0.137
42	41.668	2.1658	380	210	4.2	836	0.6	0.068
43	41.979	2.1504	387	335	6.7	2962	2.2	0.15
44	43.119	2.0962	376	152	3	627	0.5	0.07
45	44.092	2.0521	371	129	2.6	938	0.7	0.124

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The invention claimed is:

1. A compound having a structural formula of formula I:



or a pharmaceutically acceptably salt thereof, or a stereoisomer of the compound of formula I.

2. A salt of the compound of claim 1, wherein the salt is: a pharmaceutically acceptable salt of the compound having the structural formula of formula I, or

a pharmaceutically acceptable salt of the stereoisomer of the compound having the structural formula of formula I.

3. The salt according to claim 2, wherein the salt is a calcium salt.

4. A crystal of the compound of claim 1, where the crystal has a crystal form I or II, wherein:

the crystal form I exhibits diffraction peaks in a X-ray diffraction pattern at  $2\theta$  angle of  $13.3\pm 0.2$ ,  $14.0\pm 0.2$ ,  $16.9\pm 0.2$ ,  $19.1\pm 0.2$ ,  $24.4\pm 0.2$  and  $27.6\pm 0.2$ ; and

the crystal form II exhibits diffraction peaks in a X-ray diffraction pattern at  $2\theta$  angle of  $6.8\pm 0.2$ ,  $12.2\pm 0.2$ ,  $13.7\pm 0.2$ ,  $15.9\pm 0.2$ ,  $18.4\pm 0.2$  and  $23.0\pm 0.2$ .

5. The crystal of the compound of claim 4, wherein:

the diffraction peaks are present in the X-ray diffraction pattern of the crystal form I at  $2\theta$  angle of 13.3, 14.0, 16.9, 19.1, 24.4 and 27.6; and

the diffraction peaks are present in the X-ray diffraction pattern of the crystal form II at  $2\theta$  angle of 6.8, 12.2, 13.7, 15.9, 18.4 and 23.0.

6. A method of preparing the crystal of claim 4, where the crystal is of the crystal form I, the method comprising the following steps:

- adding the 5-methyltetrahydrofolate into a polar medium to form a first solution;
- regulating the pH of the first solution with alkali to form a second solution with a pH in a range of from 6 to 8;
- adding to the second solution an oxidizing agent with stirring to form a third solution;
- regulating the pH of the third solution with acid to form a fourth solution with a pH in a range of from 3 to 5; and
- crystallizing the crystal form I of the compound of formula I from the fourth solution.

7. The method according to claim 6, wherein, in the step a), the polar medium is water or a mixture of water and a water-miscible organic solvent.

8. The method according to claim 6, wherein, in the step b), the alkali is organic alkali or inorganic alkali.

9. The method according to claim 6, wherein, in the step c), the oxidizing agent is air, or oxygen or hydrogen peroxide.

10. The method according to claim 8, wherein, the inorganic alkali is selected from the group consisting of potas-

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sium hydroxide, sodium hydroxide, calcium hydroxide, magnesium hydroxide, potassium carbonate, sodium carbonate, potassium bicarbonate, and sodium bicarbonate; and the organic alkali is selected from the group consisting of ammonia, monomethylamine, 4-dimethylpyridine and piperazine.

11. The method according to claim 6, wherein, in the step d), the acid is organic acid or inorganic acid.

12. The method according to claim 11, wherein, the inorganic acid is selected from the group consisting of hydrochloric acid, sulfuric acid and hydrobromic acid; and the organic acid is selected from the group consisting of formic acid, acetic acid and phenylmethanesulfonic acid.

13. The method according to claim 6, further comprising a step of adding high active surfactant before the step c), wherein, the high active surfactant is selected from the group consisting of active carbon, active silica gel and active aluminum oxide, where an amount of the high active surfactant is in a range of from 0.05 to 10 times the mass of the 5-methyltetrahydrofolate added in the step a).

14. A method of preparing the crystal of claim 4, where the crystal is of crystal form II, the method comprising:

crystallization of the compound of formula I with the aid of ultrasonication in a polar medium at  $\text{pH}\geq 3$ .

15. The method according to claim 14, wherein, the polar medium is water or a mixture of water and a polar water-soluble organic solvent.

16. A method of preparing the crystal of claim 4, where the crystal is of crystal form II, the method comprising the following steps:

- adding a solid form of the compound of formula I into a polar medium to form a first solution comprising a solid;
- regulating the pH of the first solution with alkali to form a second solution with a pH in a range of from 6 to 10, wherein the pH is regulated until the solid is dissolved; and
- crystallizing the compound of formula I with the aid of ultrasonication, then regulating the pH of the second solution with acid to form a third solution with a pH in a range of from 3 to 6.

17. The method according to claim 16, wherein, in the step b), the alkali is organic alkali or inorganic alkali.

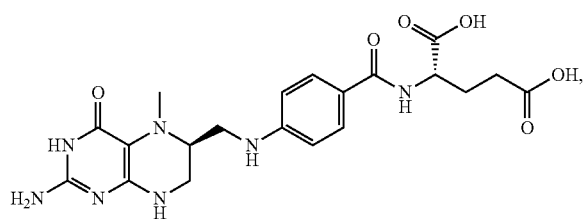
18. The method according to claim 17, wherein, the inorganic alkali is selected from the group consisting of potassium hydroxide, sodium hydroxide, calcium hydroxide, magnesium hydroxide, potassium carbonate, sodium carbonate, potassium bicarbonate, and sodium bicarbonate; and the organic alkali is selected from the group consisting of ammonia, monomethylamine, 4-dimethylpyridine and piperazine.

19. The method according to claim 16, wherein, in the step c), the acid is organic acid or inorganic acid.

20. The method according to claim 19, wherein, the inorganic acid is selected from the group consisting of hydrochloric acid, sulfuric acid and hydrobromic acid; and the organic acid is selected from the group consisting of formic acid, acetic acid and phenylmethanesulfonic acid.

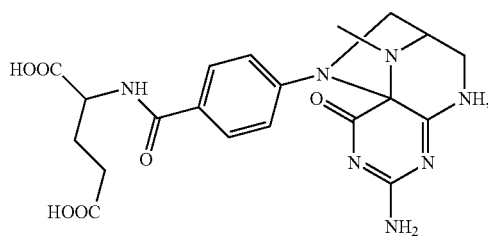
## 21

21. A method of preparing a compound of formula II:



the method comprising:

reducing the compound of formula I according to claim 1



to obtain the compound of formula II.

## 22

22. The method according to claim 21, wherein, reducing the compound of formula I to obtain the compound of formula II comprises:

dissolving the compound of formula I in water in the presence of alkali, and then reacting the compound of formula I with a reducing agent; and

obtaining the compound of formula II through separation.

23. The method according to claim 22, wherein, the reducing agent is borohydride, or reducing gas, or sulfhydryl compound.

24. The method according to claim 23, wherein, the borohydride is selected from the group consisting of sodium borohydride, potassium borohydride, and potassium tri-tert-butylborohydride; the reducing gas is selected from the group consisting of  $H_2$  and borane; and the sulfhydryl compound is selected the group consisting of from mercaptoethanol, cysteine and mesna.

25. A pharmaceutical composition comprising a compound of claim 1 and a pharmaceutically acceptable carrier.

26. The method according to claim 13, wherein the amount of the high active surfactant is in a range of from 0.5 to 2 times the mass of the 5-methyltetrahydrofolate added in the step a).

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